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FIRE-RESISTANT MATERIALS: THE BENEFITS OF STANDARDS AND CERTIFICATION

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FIRE-RESISTANT MATERIALS: THE BENEFITS OF STANDARDS AND CERTIFICATION

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The use of fire-resistant materials can be a key component of a fire prevention program in an underground mine. But not all fire-resistant materials are created equal: some materials called "fire-resistant" may produce a false sense of security. During the past several years, the Canadian Standards Association has brought together experts from the users (mines), manufacturers, regulatory agencies and others to develop stringent standards for conveyor belting, hydraulic fluids, and ventilation materials. Each of the standards has a number of categories: the choice depends on the nature and requirements of the mine. The Canadian Explosive Atmospheres Laboratory, which provided a considerable part of the technical basis for these standards, is the only agency testing and certifying materials to them. This paper will compare Canadian standards to those existing in other countries and explain the origin of some of the differences. The various tests that are incorporated will be shown.

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Introduction

"Fire-resistance" is not an easy term to define. To many people, a fire-resistant material is one that does not burn; in other words, it presents no fire hazard. People working in the field know that can be a dangerous perception. Fire-resistant materials **can** be ignited, and sometimes can burn as vigorously as materials not designated fire-resistant. Some manufacturers are concerned about their legal obligations in selling products labelled fire-resistant, and are using the term "fire-retardant" in its place. Standards usually define fire-resistant (or fire-retardant) as passing the particular tests specified in that standard, which is perhaps a non-definition.

In general, fire-resistant materials may be harder to ignite, produce less heat and propagate slower than non fire-resistant materials. Different standards specify different tests; materials passing one standard do not necessarily pass another standard. We propose that a useful operational definition of a fire-resistant material is one that does not raise the overall fire hazard of a particular operation or area. Thus, the concept of fire-resistance should be linked to the use of that material. Risk analysis can be useful in defining the degree of fire-resistance required in a particular operation.

However, this concept may not be too practicable for many people. Since many operations have similar hazards, a more practical way is to establish a committee which can examine all possible scenarios and then define appropriate tests. That should be, but is not always, the way that standards are developed.

Certification of products by an independent body to a recognized standard is useful, because it enables the user to have confidence that the products will perform to expectations. Safety characteristics, such as fire-resistance, are especially important to have certified, because the manufacturer does not receive the frequent feedback from the user as it would if, for example, the product wore out prematurely. The only time that feedback is given is on the rare occasion that disaster strikes.

Fire-resistant materials are, of course, not the only means of reducing the fire risk. Sprinklers, fire extinguishers, smoke detectors, etc. can also be used. But the advantage of using fire-resistant materials is that it is, in general, a passive method; it does not depend on any maintenance procedure, the one exception being water-containing hydraulic fluids.

Reluctance to purchase fire-resistant materials is based primarily on the additional cost of such products. Various manufacturers have stated that the increase ranges from near zero to 50%. A simple cost-benefit analysis may be useful. Say that a major fire on a conveyor belt

in a particular mine occurs once every 100 years (1% per year), and that use of a fire-resistant belt would reduce the probability of a major fire to near zero. Say that the cost of such a fire, counting material damage, loss of production, etc., but not counting loss of life, is $1,000,000. Then, the break-even point would be 0.01 x 1,000,000 =$10,000.

The Canadian Standards Association Program

The CSA established the Mine Safety Steering Committee in 1980. It, in turn, forms technical committees to draft standards in various areas, as shown in Table 1. The Technical Committees are composed of representatives of users, manufacturers, regulatory agencies and others. If proper procedures are followed, the Standards Council of Canada will approve the standards as national standards, which can be identified by the prefix "CAN".

Even after a Standard has been published, it does not become compulsory unless and until the provinces incorporate it into their respective legislation.

Table 1. Standards developed by the CSA Mine Safety program

Number	Product	Year
M421	electrical equipment installations	1985 (previous edition 1977)
M422	conveyor belts	1987
M423	hydraulic fluids	1987 (1st edition 1984)
M424.1	flameproof diesel machines	1988
M424.2	non-flameproof diesel machines	1990
M424.3	braking performance - diesel machines	1990
M425	mine hoisting	delayed
M426	blasting machines	dropped due to lack of interest
M427	ventilation materials	1991

EMR has been operating a certification service for electrical equipment since the early 1950's, and has gradually added certification of other products. It is the only laboratory in Canada able to carry out most of the tests specified in the various standards.

Conveyor Belts

Conveyor belts are potentially the most dangerous material in a mine, not only because of the large quantity used, but because they can spread a fire throughout the mine. Two major fires on conveyor belts have occurred in hard-rock mines during the past few years, one at Gaspé Copper Mines on April 1, 1987, causing one death and the temporary closing of the

mine, and the other at Ruttan Mine on Oct. 6, 1991, which produced considerable loss of production as well as material damage.

The CSA M422 Standard took six years to develop. The final version is quite complex, defining six different categories of fire-resistance (see Table 2).

Table 2. Requirements of CAN/CSA-M422-M87 Standard

Type:		A1	A2	B1A/B1B	B2	C
Flame propagation test		✓	✓	✓	✓	--
Drum-friction test	Temp.max.(°C)	325	325	400	400	400
	Parts?	yes	no	yes	no	either
Electrical surface resistance test		✓	✓	✓	✓	✓
Flame test	Flameout time-max (s)	40	40	60	60	60
	Afterglow time-max (s)	120	120	180	180	--

The flame propagation test, also known as the propane gallery test, measures the tendency of a fire to spread along a belt. It is large-scale, using a sample 900 mm (35") wide and 4 m long, with a burner consuming propane at a rate of 66 L/min. A high air velocity (1.5 m/s) promotes the spread of fire. The test is made somewhat more severe for Type A belts than Type B belts for thick (> 10 mm) belts. The test for Type B belts is essentially equivalent to the standard propane gallery test used by British Coal (formerly the National Coal Board), and similar to large-scale tests in other countries. Belts capable of passing such large-scale tests are very unlikely to contribute to a disastrous fire. The fact that Type C belts are not subjected to the flame propagation test makes them much less fire-retardant than Types A and B.

The drum-friction test measures the temperature rise on the surface of a rotating drum when a piece of belting is stalled on it. The test was originally developed in England for coal mines. Thus, a belt fails, not only if it bursts into flames, but also if sparks or glow (which may ignite methane) are observed. The maximum temperature on the drum was set so that the temperature of the outer side of the belt would not exceed the minimum ignition temperature of coal dust layers. An additional safety requirement is that the belt part during the test, thus preventing any continuing heat build-up. Canadian users indicated that a loaded belt that breaks could itself be a significant safety hazard by dumping its load down an incline. Rubber belts are much less likely to part than the PVC belts usually used for coal mines. Hence, Types A and B were subdivided into parting and non-parting to provide a choice to the user. Type B belts are allowed to generate a higher temperature because they would, in general, not be used for carrying coal. The difference between B1A and B1B is that sparks and glow are allowed in the latter.

The electrical surface resistance test determines if a static spark can be generated by the product. This test is to ensure that the belting can not cause an explosion in gassy mines. All three Types of belting must pass this test, even if they are not to be used in gassy mines. The reason for this decision was that the manufacturers stated that, with present technology, there would be no cost advantage in having the belts non-static resistant. Furthermore, since the Standard is probably already the most complex in the world; the members of the committee wanted to avoid making additional categories.

The small-scale flame test determines if a small piece of belting can be ignited by a Bunsen burner. The burner is applied for 60 s, then removed. Tests are carried out in still air. The flameout time referred to is the mean time for all flames to disappear after removal of the Bunsen burner. The limitation on afterglow time is, as in the case with the drum-friction test, to prevent ignition of methane. Most, if not all, beltings capable of passing the flame propagation test, will extinguish when lit by a Bunsen burner within a few seconds. Hence, this test is not very useful for Types A and B, except to screen out very poor beltings. For Type C beltings, it is an essential test.

The Mine Safety and Health Adminstration (MSHA) is the body that approves products for underground mines in the U.S.A. For conveyor belts, they are using a small-scale flame test which is much weaker than the flame test that we use. No other test is currently prescribed. The U.S. Bureau of Mines has carried out full-scale mine tests on MSHA-approved belts and has found that they fail. Hence, belting that has been approved only by MSHA is not recommended.

British Coal carry out similar tests to those we do, but the details as well as the requirements differ. More importantly, they do not have different categories of fire-resistance. Most belts that have been approved by British Coal would fall into CSA Types A1 or B1. Some other European countries as well as Australia also have versions of the propane gallery or other large-scale test.

Ventilation Materials

This category covers both brattice cloth and rigid ventilation tubing, which require slightly different testing procedures because of their different geometry and physical characteristics; the degree of severity is the same. Research has been carried out in the U.S.A. that shows that brattice cloth formed into tubing is no more hazardous than hanging sheets. There are four categories, as shown in Table 3.

The horizontal flammability test is a mid-scale test designed by MSHA and the U.S. Bureau of Mines to correlate with full-scale mine trials. The vertical flammability test is based on work carried out at the U.S. Bureau of Mines, and is designed to assess the hazard of using a product in a vertical shaft, where a chimney effect, which increases the intensity of fire manyfold, may occur.

British Coal uses a small-scale flame test to evaluate brattice cloth. We have shown that this test is inadequate, especially for thin materials that shrink away from the flame. In fact, 6 mil non fire-resistant polyethylene film passes this test.

Table 3. Requirements of CAN/CSA-M427-M91 Standard

Type:	VH-AS	H-AS	VH	H
Horizontal flammability test	✓	✓	✓	✓
Vertical flammability test	✓	--	✓	--
Antistatic (surface resistance) test	✓	✓	--	--

Hydraulic Fluids

The most likely scenario for a fire involving hydraulic fluids is a broken hose spraying fluid under high pressure on a hot manifold, which is simulated by the spray-ignition test. Burning of the fluid under "normal" conditions is measured by the wick test. The flammability of water-containing fluids depends critically on the water content. (In fact, although not specified in the Standard, it is advisable to monitor the level of water in the fluid.) In the case of water-oil emulsions, it is vital that the emulsion be stable, hence, the tests for stability at high temperature and through freeze-thaw cycling. Some non-aqueous fluids have been found to degrade in usage, to the point where they have lost their fire-resistance, hence the need for preconditioning the sample of fluid, which is carried out before the spray-ignition test. Since fluids are more likely to be absorbed or ingested than solid materials, there is a need to determine that the toxicity level of the fluid is low. The toxicity requirements specified in the standard were developed by Health and Welfare Canada, who review the composition of each certified product.

The Technical Committee decided to have three different categories of fire-resistance, as shown in Table 4. The majority of products certified fall into category 2.

Table 4. Requirements of CAN/CSA-M423-87 Standard

	Category 1	Category 2	Category 3
Spray ignition test: burning time (s)	< 1 s	< 30 s	< 30 s
Wick flammability test: burning time (s)	< 1 s	< 60 s	--
Fluid stability test: high temperature and freeze-thaw cycling	For water-in-oil emulsions only: < 2% oil separation; < 1% water separation		
Preconditioning test	For non-aqueous types only		
Toxicity	Non-carcinogenic, low toxicity, etc.		

Cables

The range of available types of wires and cables is vast, and there is a correspondingly vast array of CSA standards which are used to test them. Electrical cables are assessed for many different aspects of performance but, in terms of fire-resistance, CSA standards have uniformly implemented an "FT" marking and classification system across the board in order to provide users with an indication of the relative degree of fire-resistance for any particular wire and cable product. The standards specify that the marking appear on the product at a minimum specified interval. The cable flammability tests (see Table 5) are specified in CSA Standard C22.2 No. 0.3-M85 "Test Methods for Electrical Wires and Cables", which is, in turn, referred to by CSA wire and cable standards. The term "FT" stands for "Flame Tested, which was chosen because it does not imply anything about fire-resistance or retardance; it only provides information about whether a particular flame test was done. Again, this sidesteps the issue of what is meant by "fire-resistant" or "fire-retardant".

Table 5. CSA flammability classification for cables

Classification	Test Procedure	Standard Criteria
FT0	No test	
FT1	Vertical test	Burning shall cease within 60 s and not more than 25% of the extended portion of the indicator shall be burned.
FT2	Horizontal test	The charred portion of the specimen shall not exceed 100 mm measured from end to end.
FT3	Burning particles (dropping) test	Burning particles from the specimen shall not cause the newspaper to ignite.
FT4	Vertical flame test-cables in cabletrough	The length of char shall not exceed 1.5 m.
FT5	MSHA trailing cable test	The length of char shall not exceed 15 cm and the flame shall self- extinguish within 5 min.

Test FT1 is a small-scale test. It is relatively easy to pass and is widely used. Tests FT2 and FT3 are not used to as great an extent as FT1. Test FT4 is a full-scale vertical test, using a large burner, and is designed to simulate fire situations in vertical runs of cable in high-rise and other buildings. It is much more severe than FT1. Only a few test facilities are capable of conducting this test. Most cables used underground are, fortunately, of type FT4. Test FT5

does not appear in the latest edition of the CSA Standard. EMR continues to use it for its intended purpose of testing trailing cables for underground coal machines. The test, although small-scale, is made more severe, by electrically heating the cable prior to application of the flame.

Future developments

The CSA standards are written so as to be based on performance parameters, rather than material parameters, so as not to impede technological progress. Thus, manufacturers are free to use or develop new materials for their products in order to reduce costs or increase performance, provided the products satisfy the prescribed tests. However, the collective wisdom of the committee members is not sufficient to predict all new advances. For example, a conveyor system has been developed which is cable-driven; clearly, the drum-friction test is irrelevant. Therefore, the conveyor belting standard must be modified to accommodate this type of product.

Test methods too must be reviewed in view of research carried out here and elsewhere. It may be possible to use new tests which do the same job but at less expense. For example, we are evaluating a new mid-scale test developed by the U.S. Bureau of Mines to replace the current propane gallery test.

An area recognized by the various technical committees, but not addressed because of lack of data, is the production of smoke and fumes from the combustion of fire-resistant materials. Smoke obscures vision, toxic fumes can impede the ability to escape from a fire or causes health problems even from a fire that self-extinguishes, corrosive fumes can damage equipment. Germany has a test in which fumes generated by a drum-friction apparatus are passed through self-rescuer filters to animals to determine their toxicity. The Mines Accident Prevention Association Ontario has recommended that CSA adopt a test for toxic combustion products from conveyor belting. The subject of toxic fumes with respect to general usage products (e.g. consumer), as well as mine products, is an area of active research, which is expected to lead to more of a consensus on appropriate tests in the not too distant future.

Conclusions

CSA Technical Committees have developed a set of standards for products used in underground mines, based on research in this laboratory and elsewhere, that provide a high degree of safety. The certification program operated by Energy, Mines and Resources Canada ensures that products do satisfy the requirements of these standards. Use of these products will greatly reduce the risk of disastrous fires in underground mines.